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Kellie Ann Beall, Editor

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RADIATIVE HEAT TRANSFER IN FIRE MODELING

E. P. Keramida, A. N. Karayannis, A. G. Boudouvis and N. C. Markatos
Department of Chemical Engineering
National Technical University of Athens
Zografou Campus, Athens 157 80, Greece

ABSTRACT

The computational analysis of thermal radiation transfer is essential in many engineering calculations, such as those in fire modeling. Predicting possible secondary ignition due to thermal radiation is particularly important in fire safety engineering, because it enables protection of adjacent material from igniting. This paper describes the application of two widely used radiation models on a CFD product for the simulation of thermal radiation transfer in fire induced flows, in domestic sized rooms.

The case simulated is an experiment conducted by Steckler *et al.* [1] to investigate fire induced flows in a compartment measuring 2.8 m x 2.8 m in plane and 2.18 m in height, containing a fire of 62.9 KW. This particular experiment has been simulated before by Kerrison *et al.* [2], but radiative heat transfer mechanisms were neglected.

The present work proves that neglecting this important mode of heat transfer in fire modeling, leads to under-prediction of the temperature field. It also shows that theory and measurements compare well when radiation is accounted for. The results indicate that a significant percentage of the heat released by the fire, approximately 25%, is transferred via electromagnetic waves towards the bounding surfaces of the system, where it is either absorbed or reflected. Also notable is the difference between the enthalpy flow through the openings of the room with and without radiation; in the former case the energy content of the air is 34% lower than the latter case. This explains the decrease in temperature when radiation is included (see Figure 1).

Two radiation models, namely the 'discrete transfer' [3] and the 'six-flux' [4], are used to study radiative transfer in the case of a fire contained in a three-dimensional enclosure. Both models are well suited for engineering computations [5]. However, they differ in terms of accuracy of predictions and computational efficiency. In the present study the two models are compared and evaluated.

With the discrete transfer method, the total radiative flux is calculated by integrating the contributions along rays emanating from the radiative source and pointing to any selected direction. The six-flux method accounts for contributions to the radiative flux coming from only six directions, parallel to the coordinate directions. The six-flux is a differential model – a significant convenience for the discretisation of the transport equations – and offers computational efficiency. The discrete transfer model has the ability to return any desired degree of precision by increasing the number of rays projected from each physical surface and the number of zones that the domain is divided into, but it may require carefully shaped control volumes and positioning of the rays to achieve the required solution; this increases the accuracy of the solutions but adds considerably to the computational cost.

Computations were carried out with both models in Steckler's room, based on the assumption that the containing medium (a mixture of combustion gases) has uniform absorbing/emitting properties. The models were incorporated on a widely used CFD product, namely the CFX® AEA, Harwell, UK. The comparison between the flow and temperature fields of the two models, has produced reasonable agreement. The predictions of the discrete transfer model proved to be sensitive to changes in the zoning configuration and to changes in the number of rays emanating from the wall. Overall, the six-flux model proved to be superior to the discrete transfer model and, therefore, it is recommended for three-dimensional radiation computations in the cases of fire in rectangular enclosures.

Some temperature profiles of both the discrete transfer and the six-flux results are presented below.

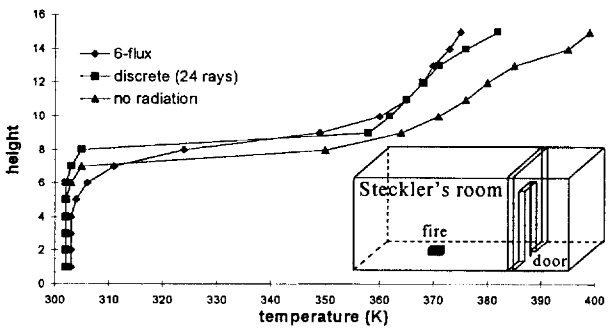

Figure 1. Door centre temperature vertical profile

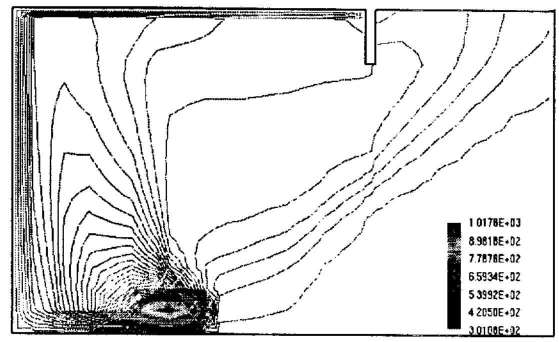

Figure 2. Mid-plane temperature contour

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